BBC RD 1978/8

1974
THE QUEEN'S AWARD TO INDUSTRY

RESEARCH DEPARTMENT

REPORT

Channel Islands link for BBC television programmes: The Alderney receiving installation

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THE BRITISH BROADCASTING CORPORATION March 1978

BBC RD 1978/8
UDC 621.391.85:
621.397.132

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Summary

Colour television programmes for the Channel Islands are obtained from the mainland by direct reception of u.h.f. transmissions on a long oversea path. The consequent variability and distortion of the signal has demanded special features of the receiving installation which are described in the report.

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March 1978
(RA-171)

CHANNEL ISLANDS LINK FOR BBC TELEVISION PROGRAMMES: THE ALDERNEY RECEIVING INSTALLATION

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1. Introduction

Possible methods for providing colour television programme feeds from the United Kingdom mainland to the Channel Islands were studied for a number of years. They included the use of s.h.f. links and under-sea cables as well as off-air reception.[1] The method finally chosen, the direct reception of the Stockland Hill (Devon) u.h.f. transmitter on Alderney, involved a long oversea path and seemed likely to give inferior quality for a significant proportion of the time.

The relative locations of the various sites are shown in Fig. 1. Programmes received at Alderney from Stockland Hill are passed on to Fremont Point in Jersey by s.h.f. link. Fremont Point is the main station for the Channel Islands and itself feeds a relay station in Guernsey and another on Alderney. It should be noted that the signals transmitted by Stockland Hill are not necessarily immaculate. Stockland Hill derives its programme feed from Caradon Hill by off-air reception at North Hessary Tor followed by an s.h.f. link; as a reserve it may also take off-air signals from Mendip. The Independent Broadcasting Authority (IBA) Channel is treated differently, having a Post Office link to Stockland Hill.

The main problems expected with the link from Stockland Hill to Alderney were variability of signal level, co-channel interference (c.c.i.) and distortion of the video signal. These are described in more detail in the following sections.

The Alderney site was originally developed by the British Post Office to relay v.h.f. monochrome television transmissions for the Independent Television Authority. Responsibility for the site subsequently passed to the States

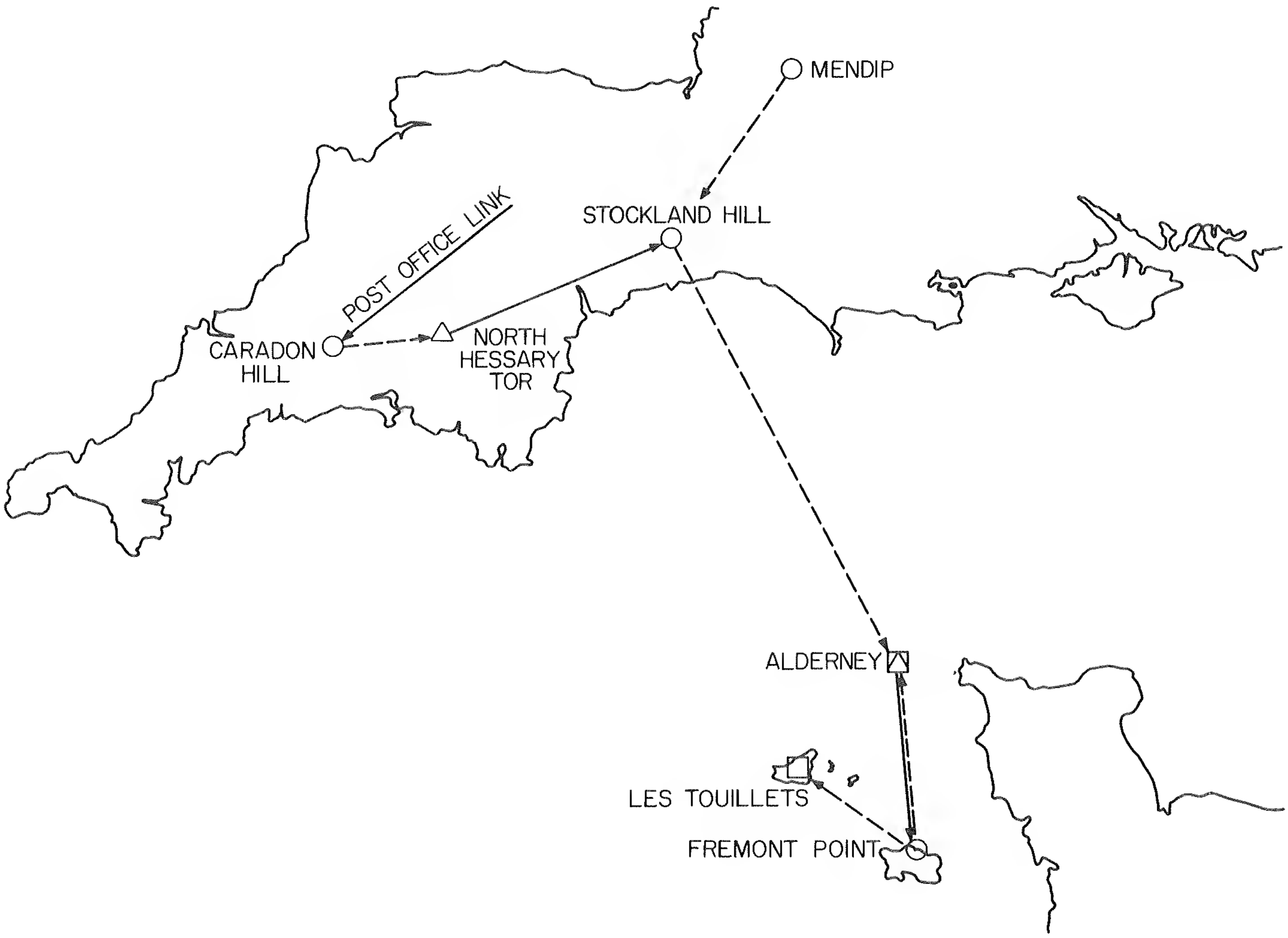

Fig. 1 - U.H.F. television distribution to the Channel Islands

○ u.h.f. main stations □ u.h.f. relay stations △ link sites ——→ s.h.f. link – – –→ rebroadcast link

of Guernsey Telecommunications Board who now lease the site to the IBA for both broadcasting authorities. The original installation[2] comprised a 29·8 m tower carrying Yagi arrays, some sloping wire aerials and, at a little distance away, two 9·14 m diameter paraboloidal reflector aerials. After strengthening, the aerial tower was available for quite substantial u.h.f. aerial arrays. Unfortunately, aviation restrictions precluded any increase in height. The paraboloidal reflector aerials were quite easy to convert to u.h.f. and this was done by the IBA. Fortunately no change of orientation was required.

2. Signal strength

Alderney is beyond the radio horizon of Stockland Hill for all attainable receiving aerial heights. Accordingly scattering mechanisms contribute to the propagation so that the signal is often weak with deep fades. At other times, particularly during the summer months, ducts are formed over the English Channel and the signal strength may rise above the free-space value. Fig. 2 shows the statistics of the signal strength derived from recordings of the Stockland Hill transmissions and illustrates the large dynamic range experienced. The field strength on Channel 33, measured at 92·5 m a.o.d.* (near the top of the aerial tower) is about 2 dB less than that on Channel 26. This difference can be explained in terms of the radiation pattern of the transmitting aerial at Stockland Hill. At a different location with a lower height, however, greater differences have been observed, possibly caused by local height-gain effects.

It may be seen from Fig. 2 that quite low signal strengths are experienced for a small percentage of the time. The quality of the link may be preserved at these times by using a high-gain aerial fitted with a pre-amplifier and by using two or more aerials in diversity. At the same time it is necessary to ensure that the receiving system, and particularly the pre-amplifier, can operate satisfactorily with the very high signal levels that can occur.

3. Co-channel interference

Rebroadcast links tend to be at risk of interference from co-channel transmitting stations. The risk is greater for the Channel Island link owing to the proximity of the continent and to the fading of the wanted signal.

Predictions of the incidence of c.c.i., carried out by a computer method,[3] indicated that receiving aerial discriminations of the order of 40 dB were desirable in some directions. In Tables 1 and 2 are listed the more important potential sources of interference and the calculated values

* above ordnance datum, which is mean sea level.

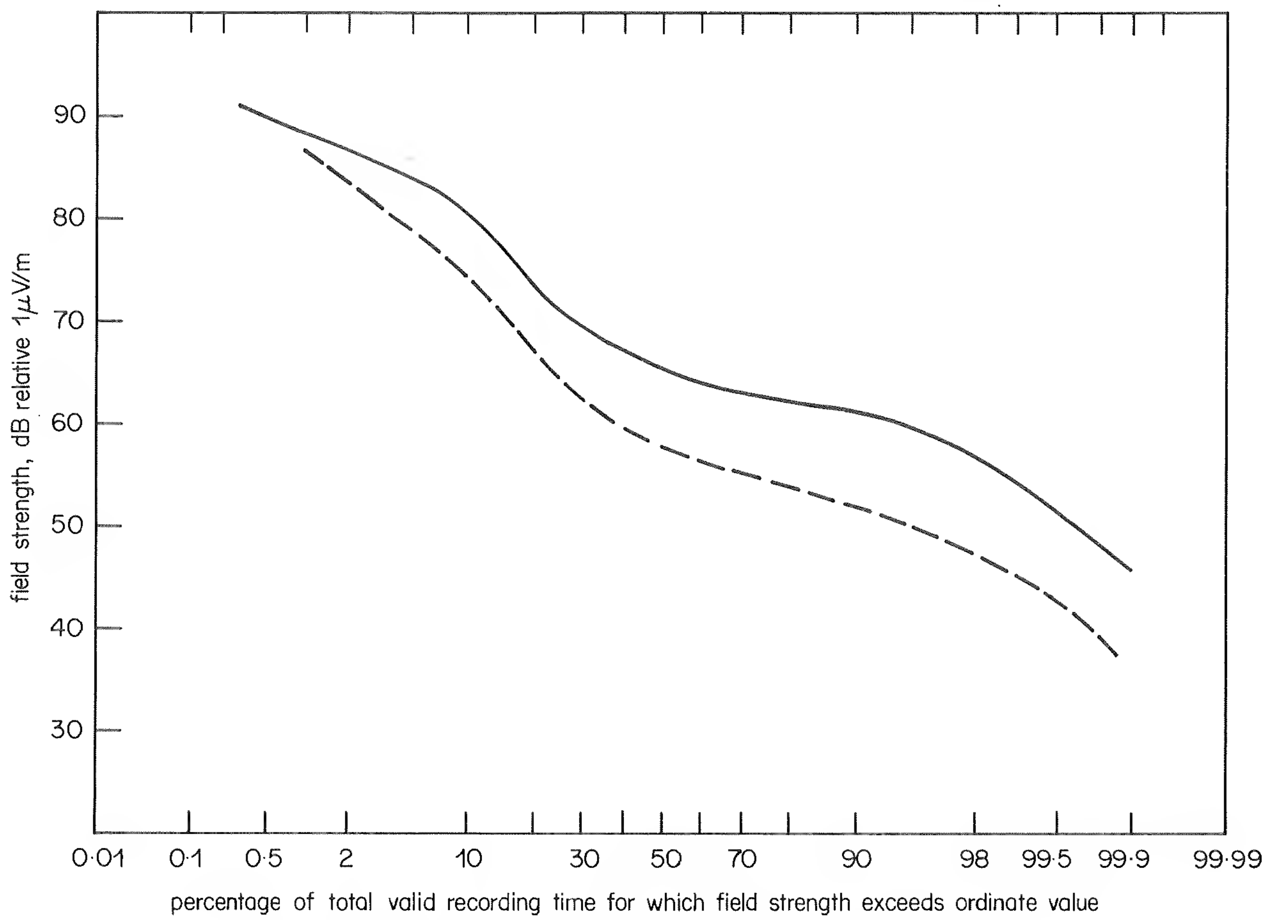

Fig. 2 - Field strength statistics of Stockland Hill, Channel 26, at Alderney
——— 94·8 m a.o.d. – – – 58·5 m a.o.d.

of aerial discrimination required to protect a signal having the median field strength. Even greater discrimination may be required to protect the signal during fades. The ability to achieve such discrimination with sometimes quite small angles and a propagation path subject to scattering was, however, in doubt. This aspect was investigated in some detail and is the subject of a separate report.[4] It was concluded that co-channel interference would degrade reception for a relatively small proportion of the time provided that the receiving aerials were designed for high directivity in the usual ways and that diversity operation was used to restrict the fading depth of the wanted signal. It was further concluded that an adaptive receiving system[9,10] capable of introducing steerable nulls on each of four channels would have insufficient speed of response to deal with a scattered signal.

TABLE 1

Required aerial directivity, Channel 26 (BBC-2) to protect the median wanted field strength for 99% time

Interfering Station	Relative bearing degrees	Aerial discrimination dB
Crystal Palace	65	39
Rouen	127	29
Kippure	7	27
Nantes-ht-Goulain	163	22
Bourges-Neuvy	154	15
Lelystad	85	13
Mynydd Machen	11	8
Rhondda	6	7
The Wrekin	24	5

TABLE 2

Required aerial directivity, Channel 33 (BBC-1) to protect the median wanted field strength for 99% time

Interfering Station	Relative bearing degrees	Aerial discrimination dB
Crystal Palace	65	39
Cancale	163	37
Rouen	127	29
Bilsdale	35	13
Kippure	7	12
Mynydd Machen	7	12
Rhondda	6	7
The Wrekin	24	5

4. Video distortion

At certain times the signal propagates in two or more different modes, giving rise to components which may destructively interfere with each other. The resultant fades are often frequency selective so that distortion of the video signal results. In particular, the chrominance/luminance ratio may vary continually with occasional colour drop-outs. The signal also carries minor distortions arising from successive modulation and demodulation in the earlier part of the programme chain.

5. Log-periodic aerial array and amplifiers

In the light of the foregoing requirements it was decided that there should be two main aerials operated in diversity. Given that one of the parabolic reflector aerials was used as one aerial of the diversity pair, a second aerial was required as high up the aerial tower as possible, in order to give an adequate vertical separation. It was also necessary for this aerial to give at least as high a signal-to-noise ratio as the parabolic reflector aerial; allowing for height-gain on the site and for system losses, this meant that the gain had to be in excess of 20 dB. There were also stringent directivity requirements. The main lobe of the horizontal radiation pattern (h.r.p.) had to be sufficiently narrow to allow rejection of an interfering station only 7° away from the direction of the wanted station and there had to be a high degree of discrimination against signals arriving from several other directions.

A log-periodic aerial[5] was chosen for the basic element of the array owing to its inherently-good front-to-back ratio (typically −30 dB over an arc of 220°) and to its low wind-loading. A total of twenty four log-periodic aerials are deployed as shown in Fig. 3, the contributions from each aerial being arranged to add in phase with equal weights. The total horizontal extent of the array is about six wavelengths. This disposition of aerials was chosen to give low side lobes adjacent to the main beam (for rejection of Kippure) as well as giving a high rejection of other important interfering transmitters such as Crystal Palace. The calculated h.r.p.s on Channel 26 (BBC-2) and 33 (BBC-1) are shown on Figs. 4 and 5 together with the directions of the more important potential sources of interference. Where these fall outside the range of bearings, e.g. for Cancale, the front-to-back ratio of the individual log-periodic aerials is added to the array factor and the total theoretical discrimination is of the order of 50 dB.

The intrinsic gain of the aerial was deduced by numerical integration of the patterns in solid angle. The calculation of the effective gain is shown in Table 3.

TABLE 3

Effective gain of log-periodic aerial array

	Channel 26		Channel 33	
Intrinsic gain, rel.$\lambda/2$ dipole		22·8 dB		23·0 dB
Deduct losses:				
Aerial feeder	0·3		0·3	
Distribution feeder	0·4		0·4	
Distribution transformers	1·0	1·7	1·0	1·7
Effective gain, rel.$\lambda/2$ dipole		21·1 dB		21·3 dB

A photograph of the array mounted near the top of the tower is shown in Fig. 6. Immediately below is an adaptive panel array used by the IBA. On the right-hand-side of the tower is the s.h.f. link aerial directed on Fremont Point while at the top of the tower may be seen a simple transmitting aerial for the local relay station.

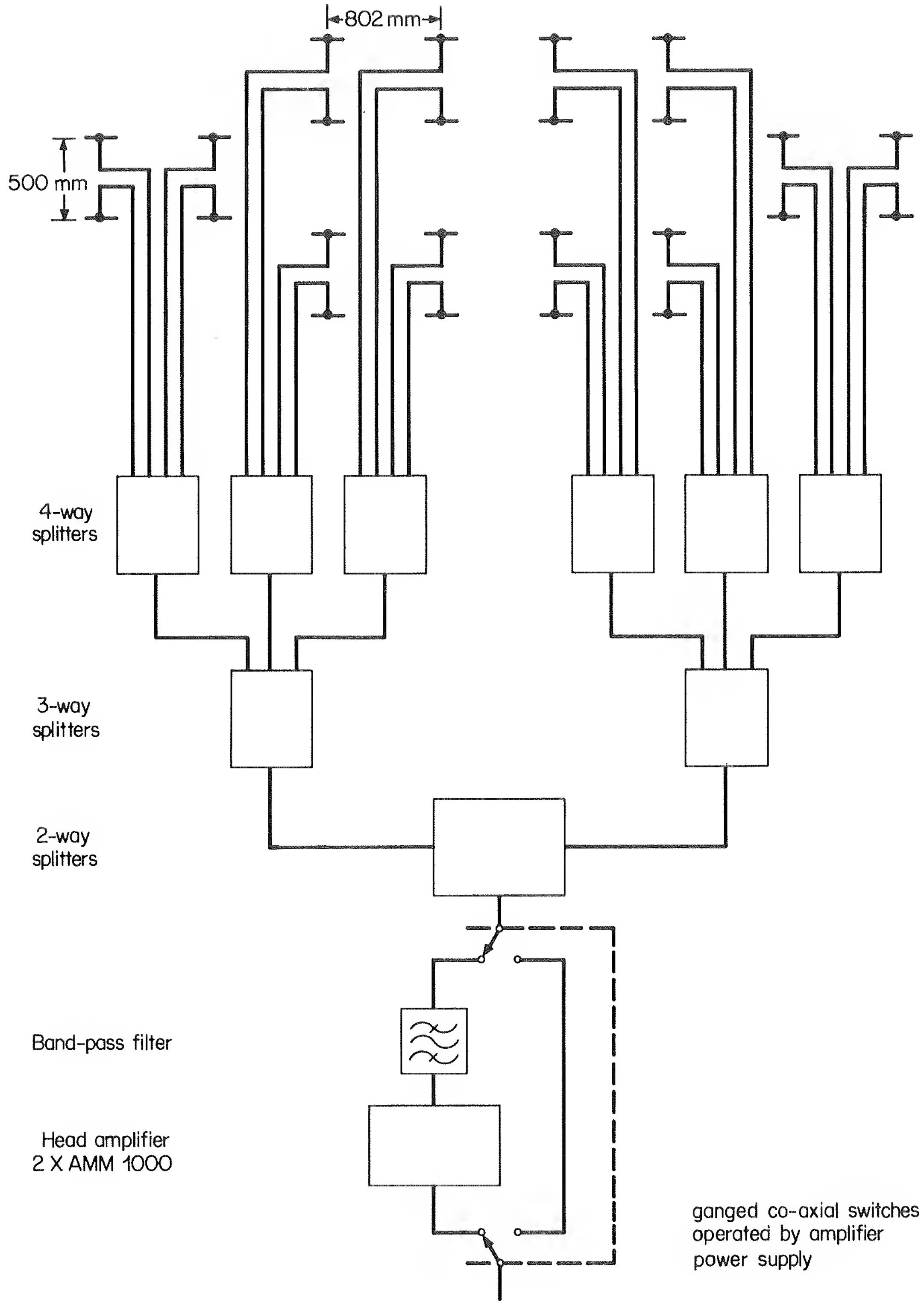

Fig. 3 - Log-periodic aerial array, distribution and head-amplifier arrangement

denotes log-periodic aerial pointing normally to plane of paper

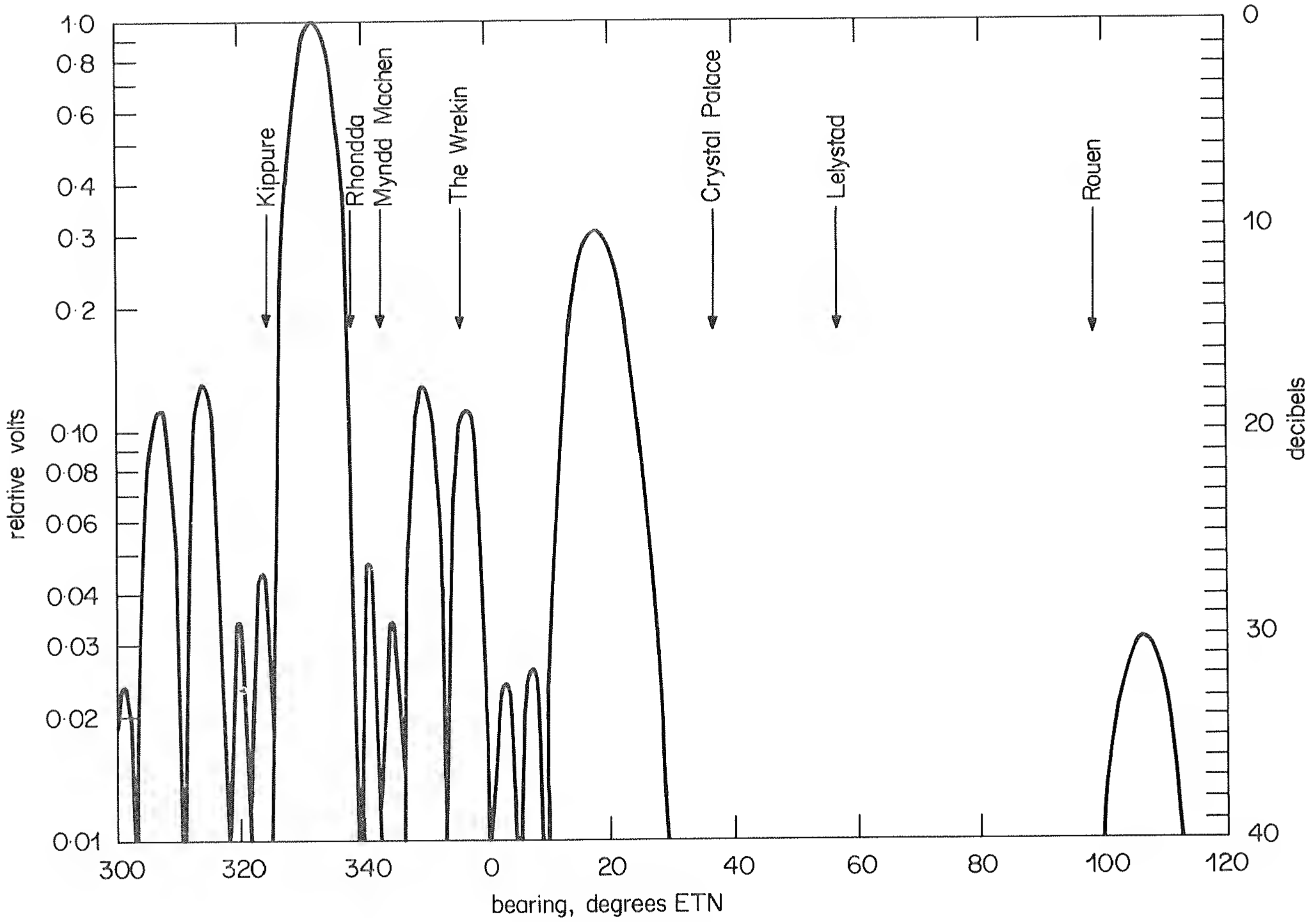

Fig. 4 - Theoretical h.r.p. of log-periodic aerial array — Channel 26 (BBC-2)

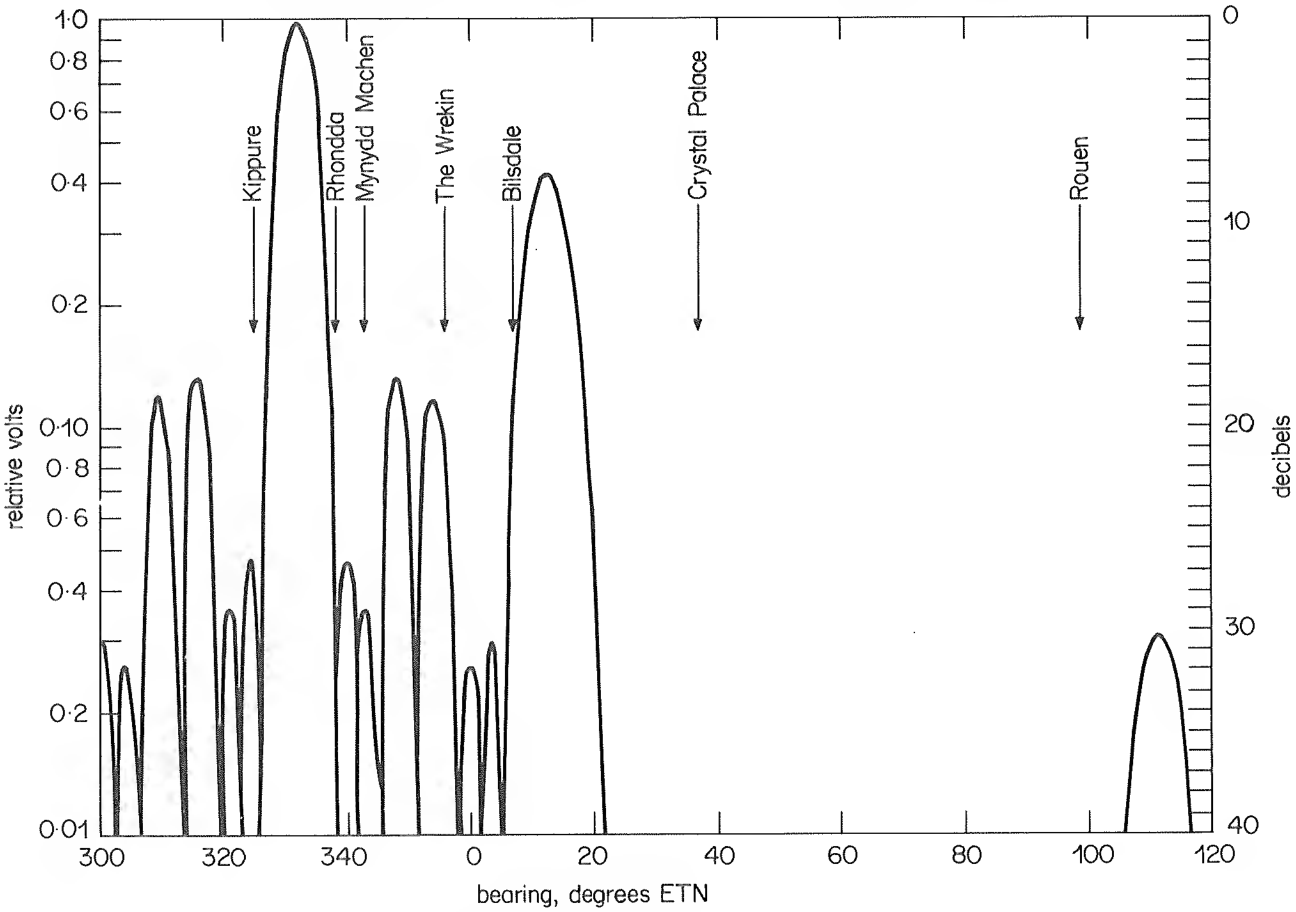

Fig. 5 - Theoretical h.r.p. of log-periodic aerial array — Channel 33 (BBC-1)

Fig. 6 - Photograph of log-periodic aerial array on tower

The head amplifiers are protected against overloading from the local transmission by means of a band-pass filter (Fig. 3). The head amplifier arrangement comprises a pair of Avantek AMM 1000 amplifiers in an Engelbrecht configuration, i.e. the signal is divided equally with a hybrid, passed through matched amplifiers and recombined. This arrangement has the advantage that a failure of one amplifier reduces the gain by only 6 dB and that the linearity of the combination is slightly better than that of a single amplifier.

The gain of the individual amplifiers is +20 dB and the noise factor is 2·8 dB. The loss in the band-pass filter and the input hybrid is 1·2 dB. The loss in the output hybrid and feeder to the receiver is 3·0 dB. Assuming a receiver noise factor of 8 dB, the system noise factor is found to be 4·2 dB.[6] The signal-to-noise ratio (unweighted) exceeded for 99% of the time is expected to be 36 dB on BBC-1.

The field strength at the aerial which is exceeded for 0·1% of the time is expected to be +92 dB(μV/m) on the strongest channel (see Fig. 2) and the corresponding peak input power to the head amplifier is −19 dB(mW). If all four channels were present at this level, the principal third-order intermodulation product (producing frequency $2f_1 - f_2$ from frequencies f_1, f_2), generated in the pre-amplifier, would have a relative level of about −50 dB. This type of interference will not affect the BBC channels. For the same input level, the in-band intermodulation product (i.e. at vision carrier plus 1·57 MHz) will be significantly less than the normal specification limit of −52 dB.

The pre-amplifier unit may be by-passed by the operation of co-axial switches. These switches are energized by the same voltage supply as the two amplifiers so that a failure of this supply automatically takes the amplifier out of circuit.

6. Parabolic reflector aerials and amplifiers

Approximately 150 m to the west of the aerial tower are two 9·14 m diameter paraboloidal reflector aerials. These are sited in a shallow gully to give additional terrain screening over a wide arc. The mean heights of the aerials are 47·8 m and 58·5 m a.o.d. These aerials are the responsibility of the IBA.

The feed units at the focal points of the parabolic reflectors give an aperture distribution which is −12 to −14 dB down at the edges of the reflector in the E-plane. A calculated h.r.p. is shown in Fig. 7. The distribution in the H-plane was not measured before installation. Measurements of the aerial gains by substitution have given values of 26·5 dB to 28·7 dB on Channel 26 and 25·5 dB to 26·5 dB on Channel 33, both values being relative to a half-wave dipole. An aerial of this size would be expected to have a realizable gain (55% efficiency) of 29·0 dB on Channel 26 and 30·0 dB on Channel 33. This disparity is believed to be due to lack of symmetry of the feed aerial in the vertical plane.

The head amplifier is provided by the IBA; it has a gain of 19 dB and a noise factor of 5 dB. The feeder and splitter transformer following the head amplifier on the upper aerial has a loss of 14 dB so that the system noise figure is found to be 7·1 dB. The signal-to-noise ratio exceeded for 99% time is expected to be 33 dB on BBC-1.

The lower parabolic reflector aerial is not fitted with a head amplifier at the present time.

7. Diversity operation

The log-periodic aerial array and the upper parabolic reflector aerial are operated in diversity. A diversity switch was designed for the purpose, the prototype being the subject of a separate report.[7] The service equipment, designed and produced by BBC Designs Department, is coded UN 9M/602. A fast-acting solid-state switch is used and is arranged to operate only during the frame blanking interval of the television waveform. This, together with equalization of feeder lengths, renders the operation of the switch largely imperceptible. As a further precaution against repeated switching when the signals from the aerials are closely comparable, a small amount of backlash (typically 1 dB) may be added.

The switching decision is based on a measurement of noise in the video output on lines 12 and 325, which contain no picture information. At present, only noise above 200 kHz is measured but it has been shown possible to extend the lower limit to 25 kHz so that the switch

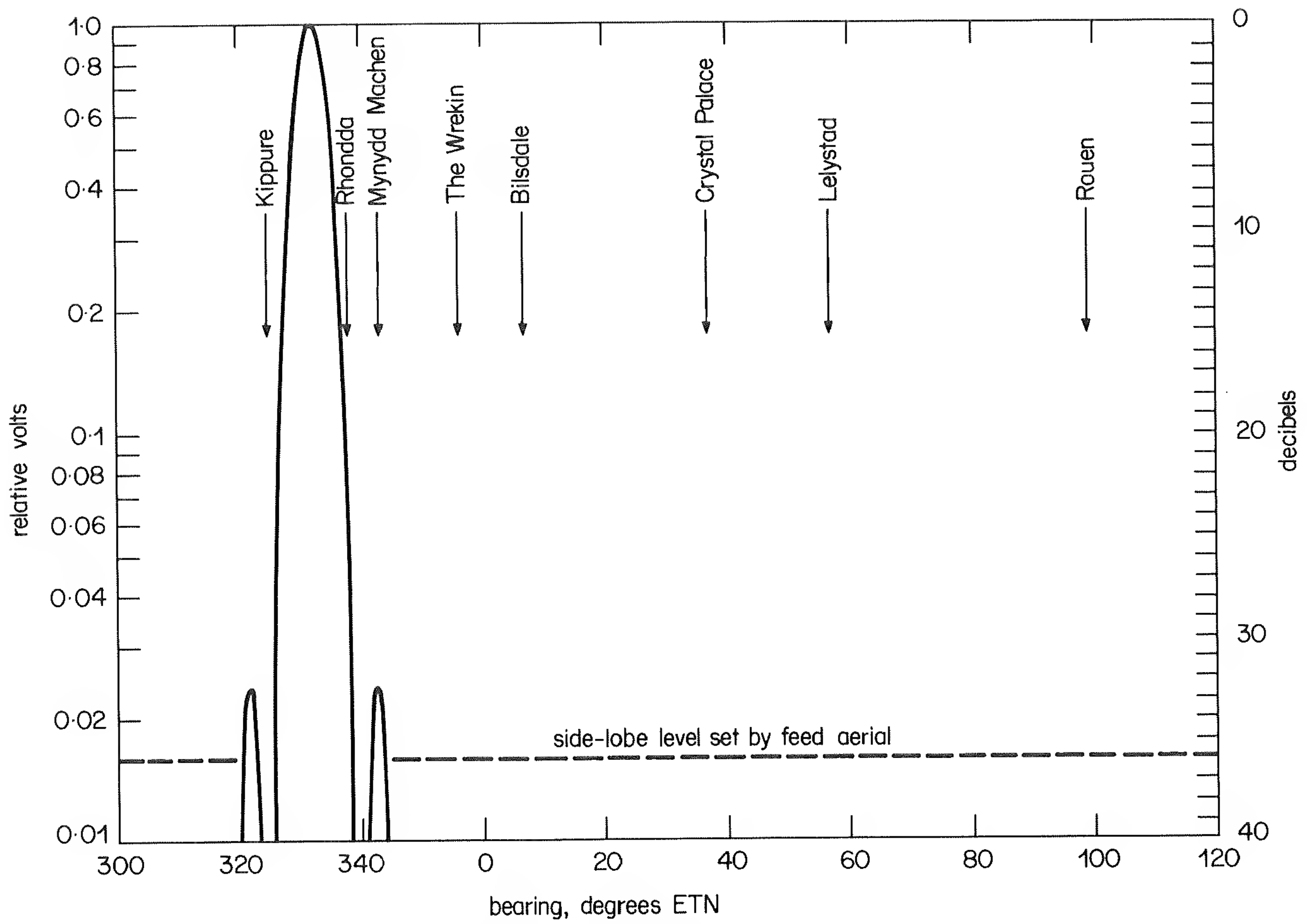

Fig. 7 - Theoretical h.r.p. of parabolic reflector aerial — Channel 26

responds also to c.c.i. from television stations having a carrier frequency offset of five-thirds line frequency. The switch is arranged to operate only when the signal/noise ratio is worse than some threshold value.

The diversity gain obtained depends on the signals from the two aerials being substantially uncorrelated. Early observations[1,7] indicated that a useful degree of diversity improvement would be obtained although the actual correlation coefficients were not known. This deficiency is currently being remedied by measurements using a digital correlator.[8]

8. Video equalization

The diversity switch assembly also contains a unit to give some equalization of the video signal. The unit has to be fast in operation in order to deal with the continual variation of colour subcarrier amplitude — sometimes referred to as 'breathing'. The correction is necessarily somewhat approximate. Further correction of any video distortion is made at the transmitter by means of an automatic video equalizer, code EQ 12M/503.

9. Overall performance

9.1. Signal-to-noise ratio

The calculated signal-to-noise ratios, allowing for practical values of diversity gain,[7] are given in Table 4. These values have been calculated assuming that the signal probability distribution of Fig. 2 and the measurements of the relative levels of the channels at the log-periodic aerial array, given in Section 2, also apply at the parabolic reflector aerial. As stated earlier, there is some evidence that this may not be wholly true and the values given for Channel 33 may be too high by up to 2 dB.

TABLE 4

Signal-to-noise ratios with diversity

	Signal-to-noise ratio exceeded for proportion of time			
	50%	95%	99%	99·9%
Channel 26 (BBC-2)	50 dB	48 dB	43 dB	35 dB
Channel 33 (BBC-1)	47 dB	45 dB	40 dB	32 dB

9.2. Co-channel interference

The percentage time for which the programmes will be protected against co-channel interference is given in Table 5. The figures are derived from results given in Reference 4 and apply to both aerials.

It will be seen that the BBC-1 signal is expected to suffer appreciable interference from the French station of Cancale for 3% of the time. This represents a total of 11

days per annum and constitutes a serious threat to reception. However, the estimate is based on a measurement of scattering through an angle of 57° and may well be pessimistic.[4] For Cancale, the angle relative to the wanted signal is 163° and moreover some of the aerials may benefit from terrain screening. At the time of writing neither this station nor Kippure are in service so that c.c.i. is not yet a serious problem.

TABLE 5

Percentage time service is protected against co-channel interference

Interfering Station	Channel	
	26(BBC-2)	33(BBC-1)
Crystal Palace	99·75%	99·36%
Kippure	99·19%	99·68%
Rouen	99·99%	99·98%
Cancale	—	98·00%
Total for all stations	98·93%	97·04%

9.3. Delayed images

The pictures received on Alderney frequently show low-level images having delays of up to 1 – 2 μs. The amplitude and delay of these images change slowly with time. They are believed to result from shipping in the English Channel. In particular, the shipping lane for west-bound traffic crosses the signal path some 10 km away and a proportion of the ships are large oil tankers riding high in the water. This effect does not constitute a serious degradation of picture quality.

10. Conclusions

The route chosen for the television programme link to the Channel Islands posed a difficult engineering problem in the design of the receiving installation. The aim in solving this problem was to achieve near-normal standards of performance in an economic way. The results of the first twelve months of service indicate that these aims have been met. In particular, significant co-channel interference appears to be occurring for less than 1% of the time, as expected.

It is predicted that there may be some increase in the incidence of interference to the BBC-1 channel as co-channel stations in France and Eire are brought into service. On the other hand, proposals now under consideration for the introduction of precision offset could reduce interference from stations in the United Kingdom.

The solution adopted by the IBA is somewhat different in that their diversity system uses one fixed aerial and one adaptive array. This is more costly and complex than the BBC installation. Unfortunately, measurements are not available at present to enable a comparison of the detailed performance of the two installations, but the technical performance of both systems is believed to be adequate to provide good picture quality for a high percentage of time.

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Printed by BBC RESEARCH DEPARTMENT, Kingswood Warren, Tadworth, Surrey, KT20 6NP